Examiner's Grp

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TI Microalloyed **steels** for cold forging and quench hardening of automotive transmission parts
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AB The microalloyed **steels** contain **C** 0.30-0.60, Si .ltoreq.0.10, **Mn** 0.15-0.65, P .ltoreq.0.10, S .ltoreq.0.10, Cr .ltoreq.0.50, Mo 0.05-0.40, Ni 0.05-0.40, B 0.0005-0.0035, Ti 0.01-0.10, and optionally Cu 0.05-0.40, Nb 0.01-0.10, V 0.01-0.10, Pb 0.01-0.20, Te 0.01-0.10, Bi 0.01-0.10 and Ca 0.0005-0.0050%. The contents of **C**, Si, **Mn**, P, and Cr can be decreased Ni addn., resulting in decreased yield point for cold forging. The low contents of Si, **Mn**, and Cr are balanced by the addn. of Mo, B, and Ti for improved hardenability after forging.

0.3-0.6 C
≤0.1 Si
0.15-0.65 Mn
≤0.1 P
≤0.1 S
0.05-0.4 Cu
0.05-0.4 Ni
≤0.5 Cr

Fe

PATENT ABSTRACTS OF JAPAN

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(54) COLD FORGING STEEL

(57)Abstract:

PURPOSE: To provide a cold forging steel capable of keeping deformation resistance at the time of cold forging at a low value and excellent in hardenability after forming.

CONSTITUTION: This steel has a composition consisting of 0.30-0.60% C, ≤0.10% Si, 0.15-0.65% Mn, ≤0.10% P, ≤0.10% S, ≤0.50% Cr, 0.05-0.40% Mo, 0.05-0.40% Ni, 0.0005-0.0035% B, 0.01-0.10% Ti, and the balance iron with inevitable impurities. Further, prescribed amounts of Cu, Nb, V, Pb, Te, Bi, and Ca can be added to this steel.

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CLAIMS

[Claim(s)]
[Claim 1] Steel for cold forging which contains [C:0.30 to 0.60% (it is the same % of the weight of a meaning and the following)] less than [Cr:0.50%], Mo:0.05-0.40%, nickel:0.05-0.40%, B:0.0005 - 0.0035%, and Ti:0.01-0.10%, respectively less than [Si:0.10%], Mn:0.15-0.65%, P:0.10% or less, and S:0.10% or less, and is characterized by the bird clapper from remainder iron
[Claim 2] Furthermore, steel for cold forging according to claim 1 which is a thing containing Cu:0.05-0.40%.
[Claim 3] Furthermore, steel for cold forging according to claim 1 or 2 which is a thing containing Nb:0.01-0.10% and/or V:0.01 - 0.10%.
[Claim 4] Furthermore, steel for cold forging according to claim 1 to 3 which is a thing containing one or more sorts chosen from the group which consists of Pb:0.01-0.20%, Te:0.01-0.10%, Bi:0.01-0.10%, and calcium:0.0005-0.0050%.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention relates to the steel for cold forging used as a material of power transfer parts, such as a ** joint outer race -- it can set to an automobile, a construction equipment, and various industrial machines -- and a gearing.
[0002]
[Description of the Prior Art] After fabricating a large diameter steel bar in a predetermined configuration cold forging or by carrying out warm forging in manufacturing power transfer parts, such as the above constant-velocity joint outer races and a gearing, it is common to perform induction hardening processing and carburization processing for hard facing. When performing especially cold forging on the occasion of such manufacture, it is required that the cold-working nature of a steel material should be excellent. Moreover, although cold-working nature contains deformability and a deformation resistance, in order to perform cold forging of the above parts, it is requirements with most important a deformation resistance being low.
[0003] As a method of reducing the deformation resistance in the case of cold forging, while reducing elements, such as C, Si, Mn, P, and Cr, the technology in which the hardenability by reduction of Si, Mn, and Cr compensates a fallen part by addition of B is proposed (for example, JP,1-38847,B, JP,2-14574,A, etc.). However, such technology had the problem that the hardenability after fabrication (especially induction hardening nature) deteriorated.
[0004]
[Problem(s) to be Solved by the Invention] this invention is made paying attention to such a situation, and it is to offer the steel for cold forging excellent also in the hardenability after fabrication while the deformation resistance at the time of cold forging can hold the purpose low.
[0005]
[Means for Solving the Problem] this invention which could attain the above-mentioned purpose is steel for cold forging which contains less than [Cr:0.50%], Mo:0.05-0.40%, nickel:0.05-0.40%, B:0.0005 - 0.0035%, and Ti:0.01-0.10%, respectively, and has a summary in a bird clapper from remainder iron and an unescapable impurity C:0.30 to 0.60% less than [Si:0.10%], Mn:0.15-0.65%, P:0.10% or less, and S:0.10% or less Moreover, as occasion demands, you may carry out specified quantity content of Cu, Nb, V, Pb, Te, Bi, the calcium, etc.
[0006]
[Function] This invention persons examined the effect of various alloying elements that the steel for cold forging which can meet the above-mentioned demand should be developed. Consequently, when adding nickel, it turns out that elements in steel, such as C, Si, Mn, P, and Cr, can be reduced further, much more reduction of a deformation resistance is attained by it, and the hardenability after fabrication (especially induction hardening nature) can moreover also be improved in spite of reduction of improvement elements in hardenability, such as Si, Mn, and Cr. And it found out that the steel for cold forging of the property for which it wishes by adjusting appropriately chemical compositions, such as Mo, B, Ti, etc. besides the above improvement elements in hardenability and nickel, was realizable, and this invention was completed. Moreover, in such steel for cold forging, it also turns out the grindability after hardening besides the fall of the deformation resistance mentioned above, and improvement in hardenability, a good thing, and that this point is sharply improved by addition of Cu although required. The reason for chemical-composition limitation in this invention is as follows.
[0007] In order to secure the intensity as parts for machine structures, it is necessary to make C:0.30 - 0.60%C contain 0.30% or more. However, if it is made to contain exceeding 0.60%, since the deformation resistance at the time of cold forging will become high too much and it will become easy to produce a quench crack, it is necessary

to make the upper limit into 0.60%.
Si: Since it is the element which raises the deformation resistance at the time of cold forging 0.10% or less although Si is an element effective in the deoxidation of steel, the content is 0.10% or less.
[0008] Mn: It has the effect of Mn turning harmless considering S as MnS 0.15 to 0.65%, and improving ductility, in order to demonstrate the effect, it is necessary to make it contain at least 0.15% and, and the improvement effect in hardenability is also acquired simultaneously. However, the superfluous addition exceeding 0.65% checks formability in cold forging.
Since P:0.10%or less P was an element which raises the deformation resistance at the time of cold forging, it limited to 0.10% or less.
[0009] Since S:0.10%or less S was an element in which the deformability at the time of cold forging is reduced, it limited to 0.10% or less.
Cr: Although less than [0.50%] Cr was an element with the effect which raises hardenability, since the deformation resistance at the time of cold forging became high and the tool life fell when it added superfluously, it could be 0.50% or less.
[0010] Mo: Although 0.05 - 0.40%Mo was an element with the effect which raises hardenability, since the deformation resistance at the time of cold forging became high and the tool life fell when it added superfluously, the content was taken as 0.05 - 0.40% of range.
[0011] nickel: It is the element which raises hardenability, without nickel raising a deformation resistance like Si, Mn, and Cr 0.05 to 0.40%, and add in order to make a deformation resistance low and to complement the hardenability fall by shortage of Si, Mn, and Cr which restricted addition. Moreover, it is an element having the effect of improving notching toughness. Although the addition effect is acquired from 0.05%, since the addition exceeding 0.40% becomes a cost rise while going up a deformation resistance, it is not desirable.
[0012] B:0.0005 - 0.0035%B is added in order to compensate the hardenability fall accompanying the shortage of Si, Mn, Cr, Mo, etc. which restricted the addition in order to reduce the deformation resistance at the time of cold forging. Although the addition effect is accepted from 0.0005%, the effect will be saturated if it exceeds 0.0035%.
[0013] Ti: Ti fixes N 0.01 to 0.10%, prevent generation of BN, and demonstrate the improvement effect in hardenability which B has. Although the effect is demonstrated from 0.01%, since the addition exceeding 0.10% causes a deformability fall resulting from inclusion generating, it is not desirable. Although this invention makes the above element a fundamental component and consists of remainder iron and an unescapable impurity, it may add Cu, Nb, V, Pb, Te, Bi, calcium, etc. as occasion demands. The content when adding these elements is as follows.
[0014] Cu: As mentioned above, 0.05-0.40%Cu is an element effective in improving the grindability after hardening, and in order it to demonstrate the effect, 0.05% or more of addition is required for it. However, if it adds exceeding 0.40%, there is fear of crack generating at the time of slabbing, and it should avoid.
[0015] Nb: V:0.01 to 0.10%, each of Nb(s) and V is elements effective in the formation of crystal detailed, and 0.01-0.10% and/or in order to demonstrate the effect, it is necessary to add it 0.01% or more in independent or the sum total. However, an effect will be saturated if the addition exceeds 0.10%.
[0016] Pb: Although each of Pb, Te, Bi(s), and calcium was machinability improvement elements, since it was also the element which is chosen from the group which consists of 0.01-0.20%, Te:0.01-0.10%, Bi:0.01-0.10%, and calcium:0.0005-0.0050% and in which the deformability at the time of cold forging is reduced, it was taken into consideration from both sides of a machinability improvement and a deformability fall, and performed above one or more sorts of addition ranges.
[0017] Although an example explains this invention still in detail below, the following example is not the thing of the property which limits this invention, and each thing marked and done to before and the after-mentioned meaning for a design change is included in the technical range of this invention.
[0018]
[Example] The dummy billet was created after the ingot at the small ingot furnace (150kg / charge), and the test specimen of the chemical composition shown in Table 1 was rolled out to the diameter:25mm steel bar. Subsequently, in order to investigate formability in cold forging, spheroidizing processing (it cools radiationally after annealing to 680 degrees C in a 730 degree-Cx4 hour [heating maintenance] ->10 degree-C/hour) was performed, and the piece of a compression test (diameter : 20mmx length : 30mm) was produced with machining.
[0019]
[Table 1]

供試材No.	化学成分 (%)												
	C	Si	Mn	P	S	Cr	Mo	Ni	Ti	B	Cu	その他	備考
1	0.47	0.04	0.46	0.008	0.004	0.21	0.09	0.15	0.020	0.0021	–	–	本発明鋼
2	0.26	0.08	0.49	0.007	0.007	0.28	0.15	0.14	0.021	0.0018	–	–	比較鋼
3	0.66	0.07	0.37	0.006	0.003	0.18	0.10	0.09	0.018	0.0018	–	–	比較鋼
4	0.45	0.07	0.41	0.009	0.008	0.17	0.11	0.11	0.016	0.0016	0.17	–	本発明鋼
5	0.49	0.16	0.44	0.007	0.006	0.19	0.10	0.11	0.021	0.0018	–	–	比較鋼
6	0.47	0.05	0.10	0.005	0.002	0.23	0.12	0.13	0.017	0.0014	–	–	比較鋼
7	0.48	0.08	0.78	0.008	0.009	0.18	0.14	0.08	0.027	0.0011	–	–	比較鋼
8	0.46	0.05	0.47	0.018	0.005	0.24	0.08	0.10	0.019	0.0019	–	–	比較鋼
9	0.49	0.07	0.44	0.005	0.017	0.23	0.14	0.14	0.024	0.0010	–	–	比較鋼
10	0.49	0.07	0.45	0.006	0.006	0.58	0.08	0.10	0.019	0.0019	–	–	比較鋼
11	0.48	0.04	0.48	0.007	0.007	0.28	0.03	0.12	0.024	0.0019	–	–	比較鋼
12	0.49	0.04	0.46	0.008	0.005	0.27	0.45	0.11	0.022	0.0013	–	–	比較鋼
13	0.45	0.03	0.45	0.008	0.002	0.27	0.15	0.03	0.018	0.0015	–	–	比較鋼
14	0.47	0.07	0.43	0.005	0.001	0.26	0.12	0.48	0.021	0.0017	–	–	比較鋼
15	0.46	0.04	0.47	0.009	0.005	0.22	0.14	0.13	0.017	0.0002	–	–	比較鋼
16	0.49	0.07	0.52	0.006	0.004	0.30	0.16	0.18	0.003	0.0023	–	–	比較鋼
17	0.46	0.07	0.49	0.006	0.006	0.26	0.12	0.10	0.020	0.0012	–	Nb: 0.03	本発明鋼
18	0.48	0.07	0.44	0.006	0.003	0.27	0.14	0.11	0.017	0.0013	–	V: 0.05	本発明鋼
19	0.46	0.09	0.44	0.007	0.004	0.21	0.11	0.09	0.028	0.0019	0.18	Nb: 0.03	本発明鋼
20	0.48	0.05	0.47	0.008	0.004	0.29	0.17	0.14	0.021	0.0015	–	Pb: 0.11	本発明鋼
21	0.47	0.07	0.46	0.008	0.003	0.31	0.14	0.13	0.019	0.0016	–	Te: 0.06	本発明鋼
22	0.47	0.08	0.48	0.009	0.004	0.30	0.12	0.16	0.024	0.0022	–	Bi: 0.04	本発明鋼
23	0.45	0.05	0.44	0.006	0.003	0.38	0.15	0.14	0.018	0.0020	–	Ca:0.003	本発明鋼

[0020] The 300t press performed the confined compression test using the above-mentioned piece of a compression test. At this time, restricted compression (compression working ratio : 60%) processing of the test piece of 30mm height was carried out to 12mm height, and the deformation resistance was investigated. The result is shown in Table 2.

[0021] Moreover, as investigation of hardenability, the diameter:20mmx length:70mm cylindrical shape test piece was produced with machining, and induction hardening processing was performed. Using a 80kHz (output; 150 Kw) RF transmitter as processing conditions, the inside of a ring top coil was moved (12 mm/sec), and it quenched in water-soluble hardening agent solution after rapid heating. The center section of this test piece was cut, the cross-section degree of hardness was measured, and the maximum surface hardness, effective case depth hardended by carburizing treatment (distance from the maximum front face to Hv=500), and the austenite grain size were investigated. The result was written together to Table 2.

[0022]

[Table 2]

供試材 No.	変形抵抗 (N/mm^2)	表面硬度 (Hv)	有効硬化層深さ (mm)	表面部のオーステナイト粒度	備考
1	833	704	2.1	9.0	本発明鋼
2	730	652	1.1	8.8	比較鋼
3	985	718	2.3	9.5	〃
4	834	706	2.2	9.4	本発明鋼
5	870	685	1.9	8.9	比較鋼
6	755	658	1.3	8.7	〃
7	976	711	2.2	9.3	〃
8	870	685	1.8	8.5	〃
9	840	695	1.8	9.0	〃
10	980	722	2.2	9.2	〃
11	795	654	1.2	9.0	〃
12	971	714	2.2	9.5	〃
13	785	668	1.3	8.8	〃
14	988	719	2.2	9.6	〃
15	784	670	1.1	8.5	〃
16	790	678	1.3	9.3	〃
17	835	709	2.2	10.8	本発明鋼
18	833	712	2.2	10.7	〃
19	838	709	2.1	10.5	〃
20	830	705	2.0	9.0	〃
21	845	711	2.1	9.5	〃
22	839	703	2.0	9.0	〃
23	830	713	2.1	9.1	〃

[0023] As the confirmatory test of the improvement effect in notching toughness by the existence of nickel addition No.13 were taken up as No.1 and comparison steel as nickel addition steel among the test specimens shown in Table 1, the piece of a JIS No. 3 V notch Charpy impact test was created for the diameter:25m steel bar with machining after hardening annealing on condition that -> (850degree-Cx 30 min, OQ) (500degree-Cx 120 min, WQ), and the impact test was performed at the humidity of a room temperature, 0 degree C, and -25 degrees C. The result is shown in Table 3.

[0024]

[Table 3]

供試材 No.	シャルピー衝撃値 (J/cm^2)			備考
	室温	0℃	−25℃	
1	152	133	83	本発明鋼
13	102	72	51	比較鋼

[0025] next, the inside of the test specimen shown in Table 1 as a confirmatory test of the improvement effect of the grindability by Cu -- as Cu addition steel -- No.4 and No. -- No.1 was taken up as 19 and Cu additive-free steel, the diameter:105mm steel bar was rolled out, induction hardening tempering processing was performed after producing the test piece which is diameter:100mmx length:215mm, and the grinding examination was performed The grinding conditions are as follows. And the grinding number till then estimated grindability for the time of the glazing in grinding and loading occurring and a machined surface becoming poor as a life of a grinding stone. The result is

shown in Table 4.
[0026] (Grinding test condition)
Abrasives-ed: Induction hardening tempering material (diameter : 100mmx length : 215mm)
Grinding stone : WA (alumina system)
grinding-stone rotational frequency: -- **-ed [1500rpm] material rotational frequency: -- 100rpm traverse speed: -- 540 mm/min -- cutting deeply -- :5-micrometer cutting cost -- :300micrometer cutting oil:PINORORU [0027]
[Table 4]

供試材 No.	研削本数 (本)	備　考
1	3	Ｃｕ無添加鋼
4	１２	Ｃｕ添加鋼
１９	１３	Ｃｕ添加鋼

[0028] It can consider as follows from the above result. When test-specimen No.2 (comparison steel) are compared with test-specimen No.1 (this invention steel), test-specimen No.2 have too low C, its maximum surface hardness is low, and its effective case depth hardended by carburizing treatment is also shallow. On the other hand, although test-specimen No.3 show the case where C is too high, they are understood that a deformation resistance is sharply high compared with test-specimen No.1.
[0029] Although test-specimen No.4 are this invention steel in which the example of Cu addition is shown, and a deformation resistance, effective case depth hardended by carburizing treatment, and surface hardness are almost equivalent compared with the thing of test-specimen No.1, it turns out that grindability is excellent as shown in Table 4.
[0030] Although test-specimen No.5 are comparison steel whose Si is too high, it turns out that a deformation resistance is too high compared with this invention steel of test-specimen No.1. Moreover, Mn content is too low comparison steel, test-specimen No.6 have the low maximum surface hardness, and effective case depth hardended by carburizing treatment is also shallow. Furthermore, although test-specimen No.7 show the comparison steel whose Mn content is too high, they are understood that a deformation resistance is sharply high compared with this invention steel of test-specimen No.1.
[0031] Test-specimen No.8 are understood that a deformation resistance is high compared with the thing of this invention steel although P is the comparison steel contained superfluously. Moreover, although test-specimen No.9 are comparison steel which S contains superfluously and the deformation resistance is almost equivalent to the thing of this invention, the crack incidence rate at the time of a confined compression test is inferior compared with test-specimen No.1.
[0032] Although test-specimen No.10 are an example of comparison which Cr contains superfluously, a deformation resistance is sharply high compared with the thing of test-specimen No.1 of this invention steel. Test-specimen No.11 have too low Mo content, and its maximum surface hardness is low, and its effective case depth hardended by carburizing treatment is also shallow. On the other hand, although the case where test-specimen No.12 have too high Mo content is shown, a deformation resistance is high compared with test-specimen No.1.
[0033] Test-specimen No.13 have too low nickel content, and its maximum surface hardness is low, and its effective case depth hardended by carburizing treatment is also shallow. On the other hand, although the case where test-specimen No.14 have too high nickel content is shown, a deformation resistance is sharply high compared with test-specimen No.1. Although test-specimen No.15 are the case where B is additive-free, baking is not contained, the maximum surface hardness is low and effective case depth hardended by carburizing treatment is also shallow. On the other hand, although the case where test-specimen No.16 have too low Ti content is shown, baking is not contained too, and the maximum surface hardness is low and effective case depth's hardended by carburizing treatment is shallow.
[0034] Although test-specimen No.17, and 18 and 19 show the case where detailed-ized elements, such as Nb and V, are added, respectively, a deformation resistance almost equivalent to test-specimen No.1, the maximum surface hardness, and effective case depth hardended by carburizing treatment are shown. Much more detailed-ization is attained especially about the austenite grain size.
[0035] Although test-specimen No.20, and 21, 22 and 23 show this invention steel which added improvement elements in machinability, such as Pb, Te, Bi, and calcium, respectively, a deformation resistance almost equivalent

to test-specimen No.1, the maximum surface hardness, and effective case depth hardended by carburizing treatment are shown.

[0036] On the other hand, this invention steel which added nickel is showing the high value also in which test temperature from the Charpy-impact-test result of Table 3 compared with the comparison steel thing which has not added nickel. moreover, the ratio in which Cu addition steel was excellent from the grinding result of Table 4 as compared with Cu additive-free steel -- it turns out that grindability is shown

[0037]

[Effect of the Invention] While this invention is constituted as mentioned above and the deformation resistance at the time of cold forging could hold low, the steel for cold forging excellent also in the hardenability after fabrication was realizable. And such steel for cold forging is the optimal as materials, such as power transfer parts which carry out induction hardening after cold forging especially a constant-velocity joint outer race, and a gearing.

[Translation done.]

TECHNICAL FIELD

[Industrial Application] this invention relates to the steel for cold forging used as a material of power transfer parts, such as a ** joint outer race -- it can set to an automobile, a construction equipment, and various industrial machines -- and a gearing.

[Translation done.]

PRIOR ART

[Description of the Prior Art] After fabricating a large diameter steel bar in a predetermined configuration cold forging or by carrying out warm forging in manufacturing power transfer parts, such as the above constant-velocity joint outer races and a gearing, it is common to perform induction hardening processing and carburization processing for hard facing. When performing especially cold forging on the occasion of such manufacture, it is required that the cold-working nature of a steel material should be excellent. Moreover, although cold-working nature contains deformability and a deformation resistance, in order to perform cold forging of the above parts, it is requirements with most important a deformation resistance being low.

[0003] As a method of reducing the deformation resistance in the case of cold forging, while reducing elements, such as C, Si, Mn, P, and Cr, the technology in which the hardenability by reduction of Si, Mn, and Cr compensates a fallen part by addition of B is proposed (for example, JP,1-38847,B, JP,2-14574,A, etc.). However, such technology had the problem that the hardenability after fabrication (especially induction hardening nature) deteriorated.

EFFECT OF THE INVENTION

[Effect of the Invention] While this invention is constituted as mentioned above and the deformation resistance at the time of cold forging could hold low, the steel for cold forging excellent also in the hardenability after fabrication was realizable. And such steel for cold forging is the optimal as materials, such as power transfer parts which carry out induction hardening after cold forging especially a constant-velocity joint outer race, and a gearing.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] this invention is made paying attention to such a situation, and it is to offer the steel for cold forging excellent also in the hardenability after fabrication while the deformation resistance at the time of cold forging can hold the purpose low.
[0005]

[Translation done.]

* NOTICES *

1. This document has been translated by computer.So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3.In the drawings, any words are not translated.

MEANS

[Means for Solving the Problem] this invention which could attain the above-mentioned purpose is steel for cold forging which contains less than [Cr:0.50%], Mo:0.05-0.40%, nickel:0.05-0.40%, B:0.0005 - 0.0035%, and Ti:0.01-0.10%, respectively, and has a summary in a bird clapper from remainder iron and an unescapable impurity C:0.30 to 0.60% less than [Si:0.10%], Mn:0.15-0.65%, P:0.10% or less, and S:0.10% or less Moreover, as occasion demands, you may carry out specified quantity content of Cu, Nb, V, Pb, Te, Bi, the calcium, etc.

[Translation done.]

OPERATION

[Function] This invention persons examined the effect of various alloying elements that the steel for cold forging which can meet the above-mentioned demand should be developed. Consequently, when adding nickel, it turns out that elements in steel, such as C, Si, Mn, P, and Cr, can be reduced further, much more reduction of a deformation resistance is attained by it, and the hardenability after fabrication (especially induction hardening nature) can moreover also be improved in spite of reduction of improvement elements in hardenability, such as Si, Mn, and Cr. And it found out that the steel for cold forging of the property for which it wishes by adjusting appropriately chemical compositions, such as Mo, B, Ti, etc. besides the above improvement elements in hardenability and nickel, was realizable, and this invention was completed. Moreover, in such steel for cold forging, it also turns out the grindability after hardening besides the fall of the deformation resistance mentioned above, and improvement in hardenability, a good thing, and that this point is sharply improved by addition of Cu although required. The reason for chemical-composition limitation in this invention is as follows.

[0007] In order to secure the intensity as parts for machine structures, it is necessary to make C:0.30 - 0.60%C contain 0.30% or more. However, if it is made to contain exceeding 0.60%, since the deformation resistance at the time of cold forging will become high too much and it will become easy to produce a quench crack, it is necessary to make the upper limit into 0.60%.

Si: Since it is the element which raises the deformation resistance at the time of cold forging 0.10% or less although Si is an element effective in the deoxidation of steel, the content is 0.10% or less.

[0008] Mn: It has the effect of Mn turning harmless considering S as MnS 0.15 to 0.65%, and improving ductility, in order to demonstrate the effect, it is necessary to make it contain at least 0.15% and, and the improvement effect in hardenability is also acquired simultaneously. However, the superfluous addition exceeding 0.65% checks formability in cold forging.

Since P:0.10%or less P was an element which raises the deformation resistance at the time of cold forging, it limited to 0.10% or less.

[0009] Since S:0.10%or less S was an element in which the deformability at the time of cold forging is reduced, it limited to 0.10% or less.

Cr: Although less than [0.50%] Cr was an element with the effect which raises hardenability, since the deformation resistance at the time of cold forging became high and the tool life fell when it added superfluously, it could be 0.50% or less.

[0010] Mo: Although 0.05 - 0.40%Mo was an element with the effect which raises hardenability, since the deformation resistance at the time of cold forging became high and the tool life fell when it added superfluously, the content was taken as 0.05 - 0.40% of range.

[0011] nickel: It is the element which raises hardenability, without nickel raising a deformation resistance like Si, Mn, and Cr 0.05 to 0.40%, and add in order to make a deformation resistance low and to complement the hardenability fall by shortage of Si, Mn, and Cr which restricted addition. Moreover, it is an element having the effect of improving notching toughness. Although the addition effect is acquired from 0.05%, since the addition exceeding 0.40% becomes a cost rise while going up a deformation resistance, it is not desirable.

[0012] B:0.0005 - 0.0035%B is added in order to compensate the hardenability fall accompanying the shortage of Si, Mn, Cr, Mo, etc. which restricted the addition in order to reduce the deformation resistance at the time of cold forging. Although the addition effect is accepted from 0.0005%, the effect will be saturated if it exceeds 0.0035%.

[0013] Ti: Ti fixes N 0.01 to 0.10%, prevent generation of BN, and demonstrate the improvement effect in hardenability which B has. Although the effect is demonstrated from 0.01%, since the addition exceeding 0.10% causes a deformability fall resulting from inclusion generating, it is not desirable. Although this invention makes the above element a fundamental component and consists of remainder iron and an unescapable impurity, it may

add Cu, Nb, V, Pb, Te, Bi, calcium, etc. as occasion demands. The content when adding these elements is as follows.

[0014] Cu: As mentioned above, 0.05-0.40%Cu is an element effective in improving the grindability after hardening, and in order it to demonstrate the effect, 0.05% or more of addition is required for it. However, if it adds exceeding 0.40%, there is fear of crack generating at the time of slabbing, and it should avoid.

[0015] Nb: V:0.01 to 0.10%, each of Nb(s) and V is elements effective in the formation of crystal detailed, and 0.01-0.10% and/or in order to demonstrate the effect, it is necessary to add it 0.01% or more in independent or the sum total. However, an effect will be saturated if the addition exceeds 0.10%.

[0016] Pb: Although each of Pb, Te, Bi(s), and calcium was machinability improvement elements, since it was also the element which is chosen from the group which consists of 0.01-0.20%, Te:0.01-0.10%, Bi:0.01-0.10%, and calcium:0.0005-0.0050% and in which the deformability at the time of cold forging is reduced, it was taken into consideration from both sides of a machinability improvement and a deformability fall, and performed above one or more sorts of addition ranges.

[0017] Although an example explains this invention still in detail below, the following example is not the thing of the property which limits this invention, and each thing marked and done to before and the after-mentioned meaning for a design change is included in the technical range of this invention.

[Translation done.]

EXAMPLE

[Example] The dummy billet was created after the ingot at the small ingot furnace (150kg / charge), and the test specimen of the chemical composition shown in Table 1 was rolled out to the diameter:25mm steel bar. Subsequently, in order to investigate formability in cold forging, spheroidizing processing (it cools radiationally after annealing to 680 degrees C in a 730 degree-Cx4 hour [heating maintenance] ->10 degree-C/hour) was performed, and the piece of a compression test (diameter : 20mmx length : 30mm) was produced with machining.
[0019]
[Table 1]

供試材 No.	化学成分 (%)												
	C	Si	Mn	P	S	Cr	Mo	Ni	Ti	B	Cu	その他	備考
1	0.47	0.04	0.46	0.008	0.004	0.21	0.09	0.15	0.020	0.0021	–	–	本発明鋼
2	0.26	0.08	0.49	0.007	0.007	0.28	0.15	0.14	0.021	0.0018	–	–	比較鋼
3	0.66	0.07	0.37	0.006	0.003	0.18	0.10	0.09	0.018	0.0018	–	–	比較鋼
4	0.45	0.07	0.41	0.009	0.008	0.17	0.11	0.11	0.016	0.0016	0.17	–	本発明鋼
5	0.49	0.16	0.44	0.007	0.006	0.19	0.10	0.11	0.021	0.0018	–	–	比較鋼
6	0.47	0.05	0.10	0.005	0.002	0.23	0.12	0.13	0.017	0.0014	–	–	比較鋼
7	0.48	0.08	0.78	0.008	0.009	0.18	0.14	0.08	0.027	0.0011	–	–	比較鋼
8	0.46	0.05	0.47	0.018	0.005	0.24	0.08	0.10	0.019	0.0019	–	–	比較鋼
9	0.49	0.07	0.44	0.005	0.017	0.23	0.14	0.14	0.024	0.0010	–	–	比較鋼
10	0.49	0.07	0.45	0.006	0.006	0.58	0.08	0.10	0.019	0.0019	–	–	比較鋼
11	0.48	0.04	0.48	0.007	0.007	0.28	0.03	0.12	0.024	0.0019	–	–	比較鋼
12	0.49	0.04	0.46	0.008	0.005	0.27	0.45	0.11	0.022	0.0013	–	–	比較鋼
13	0.45	0.03	0.45	0.008	0.002	0.27	0.15	0.03	0.018	0.0015	–	–	比較鋼
14	0.47	0.07	0.43	0.005	0.001	0.26	0.12	0.48	0.021	0.0017	–	–	比較鋼
15	0.46	0.04	0.47	0.009	0.005	0.22	0.14	0.13	0.017	0.0002	–	–	比較鋼
16	0.49	0.07	0.52	0.006	0.004	0.30	0.16	0.18	0.003	0.0023	–	–	比較鋼
17	0.46	0.07	0.49	0.006	0.006	0.26	0.12	0.10	0.020	0.0012	–	Nb: 0.03	本発明鋼
18	0.48	0.07	0.44	0.006	0.003	0.27	0.14	0.11	0.017	0.0013	–	V: 0.05	本発明鋼
19	0.46	0.09	0.44	0.007	0.004	0.21	0.11	0.09	0.028	0.0019	0.18	Nb: 0.03	本発明鋼
20	0.48	0.05	0.47	0.008	0.004	0.29	0.17	0.14	0.021	0.0015	–	Pb: 0.11	本発明鋼
21	0.47	0.07	0.46	0.008	0.003	0.31	0.14	0.13	0.019	0.0016	–	Te: 0.06	本発明鋼
22	0.47	0.08	0.48	0.009	0.004	0.30	0.12	0.16	0.024	0.0022	–	Bi: 0.04	本発明鋼
23	0.45	0.05	0.44	0.006	0.003	0.38	0.15	0.14	0.018	0.0020	–	Ca:0.003	本発明鋼

[0020] The 300t press performed the confined compression test using the above-mentioned piece of a compression test. At this time, restricted compression (compression working ratio : 60%) processing of the test piece of 30mm height was carried out to 12mm height, and the deformation resistance was investigated. The result is shown in Table 2.
[0021] Moreover, as investigation of hardenability, the diameter:20mmx length:70mm cylindrical shape test piece was produced with machining, and induction hardening processing was performed. Using a 80kHz (output; 150

Kw) RF transmitter as processing conditions, the inside of a ring top coil was moved (12 mm/sec), and it quenched in water-soluble hardening agent solution after rapid heating. The center section of this test piece was cut, the cross-section degree of hardness was measured, and the maximum surface hardness, effective case depth hardended by carburizing treatment (distance from the maximum front face to Hv=500), and the austenite grain size were investigated. The result was written together to Table 2.

[0022]

[Table 2]

供試材 No.	変形抵抗 (N/mm^2)	表面硬度 (Hv)	有効硬化層深さ (mm)	表面部のｵｰｽﾃﾅｲﾄ 粒度	備　考
1	833	704	2.1	9.0	本発明鋼
2	730	652	1.1	8.8	比較鋼
3	985	718	2.3	9.5	〃
4	834	706	2.2	9.4	本発明鋼
5	870	685	1.9	8.9	比較鋼
6	755	658	1.3	8.7	〃
7	976	711	2.2	9.3	〃
8	870	685	1.8	8.5	〃
9	840	695	1.8	9.0	〃
10	980	722	2.2	9.2	〃
11	795	654	1.2	9.0	〃
12	971	714	2.2	9.5	〃
13	785	668	1.3	8.8	〃
14	988	719	2.2	9.6	〃
15	784	670	1.1	8.5	〃
16	790	678	1.3	9.3	〃
17	835	709	2.2	10.8	本発明鋼
18	833	712	2.2	10.7	〃
19	838	709	2.1	10.5	〃
20	830	705	2.0	9.0	〃
21	845	711	2.1	9.5	〃
22	839	703	2.0	9.0	〃
23	830	713	2.1	9.1	〃

[0023] As the confirmatory test of the improvement effect in notching toughness by the existence of nickel addition No.13 were taken up as No.1 and comparison steel as nickel addition steel among the test specimens shown in Table 1, the piece of a JIS No. 3 V notch Charpy impact test was created for the diameter:25m steel bar with machining after hardening annealing on condition that -> (850degree-Cx 30 min, OQ) (500degree-Cx 120 min, WQ), and the impact test was performed at the humidity of a room temperature, 0 degree C, and -25 degrees C. The result is shown in Table 3.

[0024]

[Table 3]

供試材 No.	シャルピー衝撃値 (J/cm^2)			備　考
	室温	0℃	−25℃	
1	152	133	83	本発明鋼
13	102	72	51	比較鋼

[0025] next, the inside of the test specimen shown in Table 1 as a confirmatory test of the improvement effect of the grindability by Cu -- as Cu addition steel -- No.4 and No. -- No.1 was taken up as 19 and Cu additive-free steel, the diameter:105mm steel bar was rolled out, induction hardening tempering processing was performed after producing the test piece which is diameter:100mmx length:215mm, and the grinding examination was performed The grinding conditions are as follows. And the grinding number till then estimated grindability for the time of the glazing in grinding and loading occurring and a machined surface becoming poor as a life of a grinding stone. The result is shown in Table 4.

[0026] (Grinding test condition)

Abrasives-ed: Induction hardening tempering material (diameter : 100mmx length : 215mm)

Grinding stone : WA (alumina system)

grinding-stone rotational frequency: -- **-ed [1500rpm] material rotational frequency: -- 100rpm traverse speed: -- 540 mm/min -- cutting deeply -- :5-micrometer cutting cost -- :300micrometer cutting oil:PINORORU [0027]

[Table 4]

供試材 No.	研削本数 (本)	備　考
1	3	Ｃｕ無添加鋼
4	１２	Ｃｕ添加鋼
１９	１３	Ｃｕ添加鋼

[0028] It can consider as follows from the above result. When test-specimen No.2 (comparison steel) are compared with test-specimen No.1 (this invention steel), test-specimen No.2 have too low C, its maximum surface hardness is low, and its effective case depth hardended by carburizing treatment is also shallow. On the other hand, although test-specimen No.3 show the case where C is too high, they are understood that a deformation resistance is sharply high compared with test-specimen No.1.

[0029] Although test-specimen No.4 are this invention steel in which the example of Cu addition is shown, and a deformation resistance, effective case depth hardended by carburizing treatment, and surface hardness are almost equivalent compared with the thing of test-specimen No.1, it turns out that grindability is excellent as shown in Table 4.

[0030] Although test-specimen No.5 are comparison steel whose Si is too high, it turns out that a deformation resistance is too high compared with this invention steel of test-specimen No.1. Moreover, Mn content is too low comparison steel, test-specimen No.6 have the low maximum surface hardness, and effective case depth hardended by carburizing treatment is also shallow. Furthermore, although test-specimen No.7 show the comparison steel whose Mn content is too high, they are understood that a deformation resistance is sharply high compared with this invention steel of test-specimen No.1.

[0031] Test-specimen No.8 are understood that a deformation resistance is high compared with the thing of this invention steel although P is the comparison steel contained superfluously. Moreover, although test-specimen No.9 are comparison steel which S contains superfluously and the deformation resistance is almost equivalent to the thing of this invention, the crack incidence rate at the time of a confined compression test is inferior compared with test-specimen No.1.

[0032] Although test-specimen No.10 are an example of comparison which Cr contains superfluously, a deformation resistance is sharply high compared with the thing of test-specimen No.1 of this invention steel. Test-specimen No.11 have too low Mo content, and its maximum surface hardness is low, and its effective case depth hardended by carburizing treatment is also shallow. On the other hand, although the case where test-specimen No.12 have too high Mo content is shown, a deformation resistance is high compared with test-specimen No.1.

[0033] Test-specimen No.13 have too low nickel content, and its maximum surface hardness is low, and its effective case depth hardended by carburizing treatment is also shallow. On the other hand, although the case where test-specimen No.14 have too high nickel content is shown, a deformation resistance is sharply high compared with test-specimen No.1. Although test-specimen No.15 are the case where B is additive-free, baking is not contained, the maximum surface hardness is low and effective case depth hardended by carburizing treatment is also shallow. On the other hand, although the case where test-specimen No.16 have too low Ti content is shown, baking is not contained too, and the maximum surface hardness is low and effective case depth's hardended by carburizing

treatment is shallow.

[0034] Although test-specimen No.17, and 18 and 19 show the case where detailed-ized elements, such as Nb and V, are added, respectively, a deformation resistance almost equivalent to test-specimen No.1, the maximum surface hardness, and effective case depth hardended by carburizing treatment are shown. Much more detailed-ization is attained especially about the austenite grain size.

[0035] Although test-specimen No.20, and 21, 22 and 23 show this invention steel which added improvement elements in machinability, such as Pb, Te, Bi, and calcium, respectively, a deformation resistance almost equivalent to test-specimen No.1, the maximum surface hardness, and effective case depth hardended by carburizing treatment are shown.

[0036] On the other hand, this invention steel which added nickel is showing the high value also in which test temperature from the Charpy-impact-test result of Table 3 compared with the comparison steel thing which has not added nickel. moreover, the ratio in which Cu addition steel was excellent from the grinding result of Table 4 as compared with Cu additive-free steel -- it turns out that grindability is shown

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[Translation done.]